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TECHNICAL REPORT 82-02

Semi-Annual Technical Report:

The Development and Application of Advanced Video and Microcomputer-Based Command and Control (C2) Systems

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December, 1982

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Video telecommunications are applicable to Command and Control requirements in resolving complex issues through multi-station videoteleconferencing systems constructed within the offices of key decision-makers. Spatial representation of information is available at low-cost through microprocessor technology. Software written to execute on an APPLE II requires little user training to operate. The recording of computer images on video-tape is fraught with problems; herein two solutions are offered.

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SUMMARY

This Semi-Annual Technical Report covers the period from April 1,1982 to September 30, 1982. The tasks/objectives and/or purposes of the overall project are connected with the design, development, demonstration and transfer of advanced computer-based command and control (C2), video-teleconferencing and counter-terrorist systems. This report covers work in the area of video-based and microprocessor systems research, analysis, prototype development and installation. The technical problems addressed include: the system design concepts behind multi-node, low-bandwith video-teleconferencing, current efforts in virtual space and shared data and the five-node configuration, spatial representation of information utilizing a general purpose micro processor (MICRO-SDMS), and a report on methods of recording computer generated images onto videotape. Other discussions include how developments in these areas can be exploited for Department of Defense (DoD) use for group problem-solving, video telecommunications, training, and information management and dissemination. The general methods employed include three reports each discussing one individual phase of research or group of contract tasks. Technical summaries and conclusions include a set of recommendations regarding how current and future video and microprocessor technology can be used or enhanced in a variety of defense contexts. Future research will summarize and integrate all of the work peformed during the two-year contract period.

<u>CONTENTS</u>

1.Ø VIDEO TELECONFERENCING

1.1 Video Telecommunications

It is imperative that the research and development (R&D) process connected with application and transfer of advanced Command and Control (C2) systems be conducted in "real-life" environments utilizing personnel familiar with the problems encountered during actual C2 exercises. Specifically, such problems may be categorized as follows:

1.1.1 Ineffective Use of the Office

As a meeting place, the office is not used to its full advantage. Very often, primary decision-makers are required to attend meetings at inconvenient locations and disagreeable times merely because of the lack of any other means of effective inter-personal communications. Face-to-face meetings have been proven to be more effective than those conducted solely by telephone.

Conference rooms are usually set aside for meetings between managers to provide a central location, equidistant and convenient to all participants. Meetings held in these distant locations are most advantageous in that the conferee is removed from the confines of his office and all the disruptions of the telephone, visitors, employees and staff. However, once away from his domain, the manager no longer has his fingertips a file-drawer of all of his important documents; he is usually removed from his staff who may be needed for assistance or information. Clearly, any meeting place which requires removing the executive away from his office has disadvantages.

In comparison, meetings held in the office usually require at least one participant to suffer the same disadvantages as he would in attending a meeting held elsewhere. Multiple people at an office meeting create new problems due to cramped space, and lack of appropriate work tables etc.

Decision-makers need and deserve the freedom to conduct and attend meetings from the most effective location, that is, in their own offices. This then presumes that for all but extraordinary situations most meetings would be best conducted in an office and over the telephone, unless there are more participants than existing telephone communications can support.

1.1.2 Lack of Visual Contact

During telephone meetings there is a lack of direct visual contact. This problem is inherent in all communications which take place over standard telephone systems. It is not unusual for misunderstandings to occur while in the "voice only" mode. It is important to be able to see the other party, to discern his non-verbal reaction to a question or comment addressed to him. This reaction will assist the speaker in determining the level of enthusiasm which is being generated by his suggestions.

Without these kinds of indicators (sour face, nearly asleep, big smile, etc.), it becomes a guessing game of how he is being received.

Non-visual telephone communications are generally two-party in nature and require considerable advance planning to assemble both the conferees and the communications links. Usually meetings of the highest order are not planned in advance, but occur due to unforeseen circumstances and have a very short lead time in which to assemble the participants and materials. The visual and personal aspects of a conference room is highly preferable in those instances where ideas must be "bounced off" decision-makers.

1.1.3 No Perception of Spatiality

Our telephone industry tells us that the future will indeed bring us the picture phone. This device will permit both voice and image communications. This advance will most certainly be a step in the right direction, but it too lacks important features necessary for effective communication between high level decision-makers. Unless this new product can accommodate the feeling of presence of the conferees, it will fall short in providing an effective representation of "real people" attending a meeting.

There is an alternative which provides a solution to the lack of presence in a picture phone conference. This alternative provides an additional dimension in telephone communications, that of spatiality. In the concept of spatiality, each participant is represented by his or her surrogate. These surrogates are positioned in the room in the same way they would be if they were physically present. For example, their voices would come from across the table/ desk from different sides and the principal would not be required to distinguish who was speaking by discerning from degraded images or distorted audio quality, but rather, the direction from which the sound is emanating. However, until now the potentials of spatiality have not been investigated.

We appreciate the fact that inventions such as the picture phone will advance the method by which people communicate. However , these improvements are largely for two-node systems, whose participants are known to each other. In government or business, conferences are often held among new or only general acquaintances. Attempts to distinguish between individual voices without the advantage of spatiality would be a difficult chore. The images as well may not be of broadcast TV quality, and present the same instant recognition problem which would again be solved through spaciality. For example, the decision-maker need not remember what the person looks like, but, that the person on the right is a technician for XYZ Company, and the person on the left is his boss. Simple recognition in this manner will speed the conversation and increase the "throughput" of the meeting.

1.1.4 Inability to Share Documents

Almost as important as the participants of a meeting are the documents and materials which they bring with them. Moreover, the ability to share a single document, drawing or chart is essential to illustrative communication. The ability to share data among several decision-makers at the same time is common to computer systems which permit timesharing. Also, textual da is easily available through the newer computer mail systems. su-ally the two are not available together. Of course, phone s-tems provide facsimile (FAX) systems, but the transmission a document is sometimes a long and tedious procedure. Nearly all of these capabilities may be used in conjunction with a nearby telephone, however both voice and data transmission modes in these examples are not components of a single system but distinctly separate and complete with the undesirable peculiarities of each.

Ideal data sharing occurs during the conference or meeting when the conference leader hands out the agenda, and the meeting proceeds with all participants discussing the same topics. Often, charts, drawings, and textual materials are introduced in support of the speaker's main point. Discussions relating to concepts developed during the meeting may be illustrated on notepads or chalkboards in such a way as to permit each participant to add or change it as necessary.

These capabilities are usually necessary for a successful meeting and are not generally available through the current telephone systems or as a commercial package. Indeed, the ability to share documents among conferees is crucial to the success of meetings conducted by decision-makers.

1.2 Video-Teleconference Systems Design

When it comes to group decision-making, every meeting environment has its own set of benefits and detriments. For example, face-to-face meetings can be very effective for resolving complex problems. Conference calls, however, can be quicker and less expensive. Similarly, meetings held within an office benefit from an intimate, information-at-your-fingertips environment.

The current task of Computer Systems Management is to combine a number of meeting alternatives in such a way as to incorporate all the productive elements of each alternative while deleting the unproductive ones. A multi-station videoconferencing system with shared graphics capability, constructed within the offices of key decision-makers, is perhaps the most effective mix of meeting options currently available.

1.2.1 Effective Use of the Office as a Meeting Place

The office is an effective meeting place because the host executive has many resources at his fingertips--data files, rolodex, support staff, etc. Of course, out-of-town visitors are at a disadvantage because all their resources are "back at the office". One way to improve this situation is to install teleconference rooms within the buildings occupied by the decision-makers. Although this eliminates travel costs, the executives still do not have all the necessary "fingertip" resources. They have to ask an assistant to fetch the files "upstairs in the office."

A more efficient approach is to install the teleconferencing equipment right inside the executive's suite. That way, each decision-maker can attend a meeting while staying in his office chair, having immediate access to pertinent materials. Administrators can conduct face-to-face group meetings without dragging extra chairs into cramped quarters, serving coffee to guests, or passing around ashtrays. The time and expense of travel (whether across the country or down the hall) is eradicated as is the need for maintaining a space-consuming "teleconference room".

There are other concerns, however; the notion of installing videoconferencing equipment within the office creates fear in the hearts of executives. They are distressed by the thought of messing up their orderly interiors with cameras, lights, microphones, technicians, and cables. This need not be the case.

Integrating such equipment can be done tastefully. For example, wood-grain cabinets make attractive enclosures for cameras, monitors, and speakers. By extending these cabinets to the ceiling, connector cables run up inside them to the ubiquitous "suspended ceiling" where the stay out of sight.

Glaring TV lights are unnecessary with the installation of special low-light TV cameras. Such cameras still need more illumination than that provided by conventional office lighting.

Ceiling-mounted "accent lights" like those used in art galleries fulfill lighting requirements while adding a pleasing "designer look".

Microphones are unobtrusive as well. Whereas desktop mikes clutter the executive's desk and clip-on lavalier mikes require the wearing of an obnoxious cable, shotgun microphones hung from the ceiling eliminate clutter and cables while staying out of sight. In addition, their narrow pick-up path reduces audio feedback problems.

Videoconference equipment implies the need for camera operators and video technicians. Not so. Research indicates that for most in-office videoconferences, a "cameraman" is unnecessary. This is because the camera operator's function is to follow the action. Since executives conduct their in-office videoconferences while seated at their desks, there is no action to follow. And since research indicates that viewers consistently prefer head-and-shoulder shots 10% larger than life, no camera operator is needed to zoom the camera in or out.

Keeping camera operators and technicians out of the office assures the privacy and spontaneity of the conversation. But aren't technicians still needed to set up the equipment before each conference? Possibly, but by accurately designing the system, all buttons and dials can be set during installation so they need no further readjustment. All the executive has to do is touch the "power on" button and begin the meeting. The technicians serve only to service remote equipment and to provide standby support in case of "crashes". With improvements in technology, when the research equipment has led to production facilities, even this need could be eliminated.

In this videoconference system, every attempt is made to keep things simple and unobtrusive. This prevents hardware concerns from overshadowing the substance of the meeting, resulting in the truly effective use of the office as a videoconference meeting place.

1.2.2 Visual Contact During Telephone Meetings

Voice-only conference calls cannot reveal the subtle nonverbal behavior that is crucial to top-level meetings. In any conventional conference where the partiicipants meet face-to-face, there is a variety of information that is passed between the individual that is of non-verbal nature.

Individuals defer to each other based on such factors as an open or closed mouth, a raised eyebrow, a hand gesture, a change in posture. Each response has an accepted context, and culturally based content. Each provides the kind of information conventionally used in two-way audio radio communication: the "roger", "over" and "out".

These signals are of even greater importance when three or more individuals are in conference. In a telephone meeting involving more than two individuals, "race" conditions occur resulting from the fits and starts caused by inadequate cueing of the starts and stops of an individuals sentences.

Video-teleconferencing restores this ability. Executives can establish eye contact when making a key point. They can detect the sincerity of the speakers' comments. They can witness signs of interest or boredom and alter their speech accordingly.

1.2.3 Perception of Spatiality

When three or more people confer for a conference call, the conversation becomes uncomfortable. When the speaker asks, "What do you think of that?", the listeners aren't sure who is supposed to respond. And if the conferees don't know each other, one person might respond without introducing himself first. Thus the listener may not be able to detect who is speaking.

Videoconference calls clear up the confusion somewhat. At least a conferee can associate the voice with a face when someone speaks out. But again in a multi-station arrangement, if the speaker asks, "What do you think of that?", the conferees cannot detect who the question is being addressed to. This is because most videoconference systems do not satisfactorily create the illusion of a face-to-face meeting. They lack the "directed gaze", that is, the ability to direct a question to one person in a group by simply gazing in the person's direction.

The reason for this insufficiency is simple. Each conference station has only one camera pointed squarely at the conferee. Thus all conferees stare straight forward at their cameras (and at the speaker). If the teleconference network has multiple stations, the conferee will typically be watching a bank of television monitors, with each conferee staring straight forward. This is a very rigid and disturbing sight to see.

Alternatively, when the monitors are separated in a semi-circle around the conferee's desk (Los Angeles on the left, Chigago in the center, New York on the right) and a camera is mounted above each monitor, a sense of "virtual space" would be created, thus permitting directed gaze. For example if the speaker asked, "What do you think?", while glancing over to the monitor at the right, New York would respond instantly while Los Angeles and Chicago remained silent. This occurs because when the speaker looks in the direction of the New York monitor, the New York camera sees the speaker head-on. The cameras above the Los Angeles monitor and the Chicago monitor see only the speaker's profile.

In face-to-face meetings, such nonverbal directions happens naturally. Perhaps that's why such meetings run so smoothly. The importance of incorporating nonverbal behavior into teleconferencing has been the source of considerable research and debate. Certainly such cues are not important when arranging schedules, coordinating details, and solving technical problems. But nonverbal communication is immensely important during crisis management calls, in negotiation conversations, and when the speaker is trying to persuade the listener (la Plante, 1971; Williams, 1975; Morley, 1980). Since crisis management, negotiation, and persuasion are of top priority to this proposal, the virtual space approach to videoconferencing is well-suited indeed.

The physical design and appearance of a virtual space videoconference system in the office is very different from that of the conventional teleconferencing room. Instead of lining up a row of large monitors on the wall (one monitor for each station in the network), the virtual space design isolates each monitor in its own cabinet (called a "conferee surrogate"), along with a camera and a loudspeaker. Isolating the audio output of each station through its own surrogate creates a "quadraphonic stereo" effect. This enables the conferee to hear where the voice is coming from, as well as to see the speaker's lips moving.

Retrofitting existing offices with such videoconferencing equipment is relatively easy. All cables run above the ceiling and drop down through the floor-to-ceiling cabinets to the equipment within.

Two experimental virtual space systems document the potential of the concept (DDI, 1981, Bell Northern, 1982). Users are consistently impressed with the naturalness of the arrangement. Within seconds, newcomers exchange non-verbal cues as though their co-conferees were right in the room with them.

As with other aspects of this project, the idea behind the concept is to make video-teleconferencing more natural than teleconference calls and more convenient than conventional videoconferences. Arranging videoconference equipment to permit the perception of spaciality achieves these goals. The net result is more effective face-to-face meetings and less costly executive communications.

1.2.4 Simultaneous Sharing of Documents

An important aspect of every conference or meeting is the "shared data": agendas, hand-outs, slides, vu-graphs, blackboard, etc. Their importance is evidenced by the millions of dollars spent on business graphics annually. Curiously, the topic is only now beginning to be investigated by the teleconference industry. Little research currently exists.

There are many telegraphic systems available on the market: facsimile, computer timesharing, electronic blackboards, modem-driven plotters, etc. All can be used as add-ons to video-conferencing systems, but none of these systems are current, integral elements. This means that the video system and the graphics system work independently with radically different methods of transmission and encoding.

There is one experimental system however that was planned from the start to be part of a videoconference system. It is called the Shared Graphics Work Space (DDI, 1981), and it is part of the earlier four-node full-bandwidth virtual space system. Each videoconference station has an overhead camera pointed at a square on the desk. When a conferee lays a document on the square, all conferees see it on their graphics monitors. As the conferee annotates the document, all conferees watch him drawing, underlining, pointing, etc.

So that each conferee can show his own documents, a central video mixer combined the sum of the images in a multiple dissolve. This also provides the graphics system with group interaction. For example, one conferee could write on another conferee's document by placing a blank sheet on his own square and drawing circles, underlines, margin notes, etc. Unfortunately, this multiple dissolve muddles the picture, making text illegible.

A way to improve this technique while keeping costs down is to use channels. The graphics shown by the first station appear on Channel 1. The graphics from another station appear on Channel 2. And so on. Each station has a channel selector which enables individual conferees to call up anyone else's illustrations.

This system is easy to use and to install. There is no lag time between when a station sends the image and when the conferees see it. The system is interactive in that every meeting participant can send images, not just the principal. This ability to share documents tremendously increases the effectiveness of videoconferencing as an executive communications tool.

1.3 Current Efforts in Teleconferencing

The list of companies involved in teleconferencing is long and growing longer. This list consist of large companies such as the AT&T, NEC, and Western Union, as well as smaller but equally sophisticated companies.

The current interest in teleconferencing being expressed by some of these corporations is a reflection of the increasing awareness of the costs incurred when a meeting is arranged requiring the physical presence of individuals normally separated by great distance.

In previous sections of this report we have discussed some of the problems engendered in any conference which is held in a location other than the attendee's office. In any such remote conference there are the overt costs which contribute to the expense such as hotel rooms, meals, transportation and related incidental expenses. There are also the less tangible costs incurred by the loss of time, the difficulties and lack of access to common data by the participants.

Video teleconferencing may reduce these costs by providing the electronic presence of an individual. As yet the companies mentioned above are working on stations that provide full video, but without the elements of spatiality that contributes to better communication, and without the integration of shared data with the conference. Key efforts have been in providing full color stations and research has been with the various encoding schemes such as interframe coding, intraframe coding, and Bell's method of motion compensation encoding.

The inability of a video teleconference to provide adequate non-verbal queues; the difficulty in presenting data at a video teleconference in a meaningful way; the difficulties encountered in the used of video-teleconferencing by individual who have not had an appropriate technical background; all of these contribute to an environment that lacks key elements of a successful conference.

Current state-of-the-art systems are an improvement over audio-only systems, but the missing key elements diminish the effectiveness of the system.

1.4 Virtual Space

Research at Decisions and Designs, Inc. (McLean Virginia) produced a four-station system, described earlier, that incorporated video that was linked by ordinary coaxial cable, hardwired between each of the stations.

Figure 1 shows the relative interfaces in a Virtual Space environment. (Note that for a complete Virtual Space configuration, the total number of camera/monitor stations required is equal to N x N-1; where N is the number of individuals participating in the conference.)

VIRTUAL SPACE
TELECONFERENCING
NETWORK

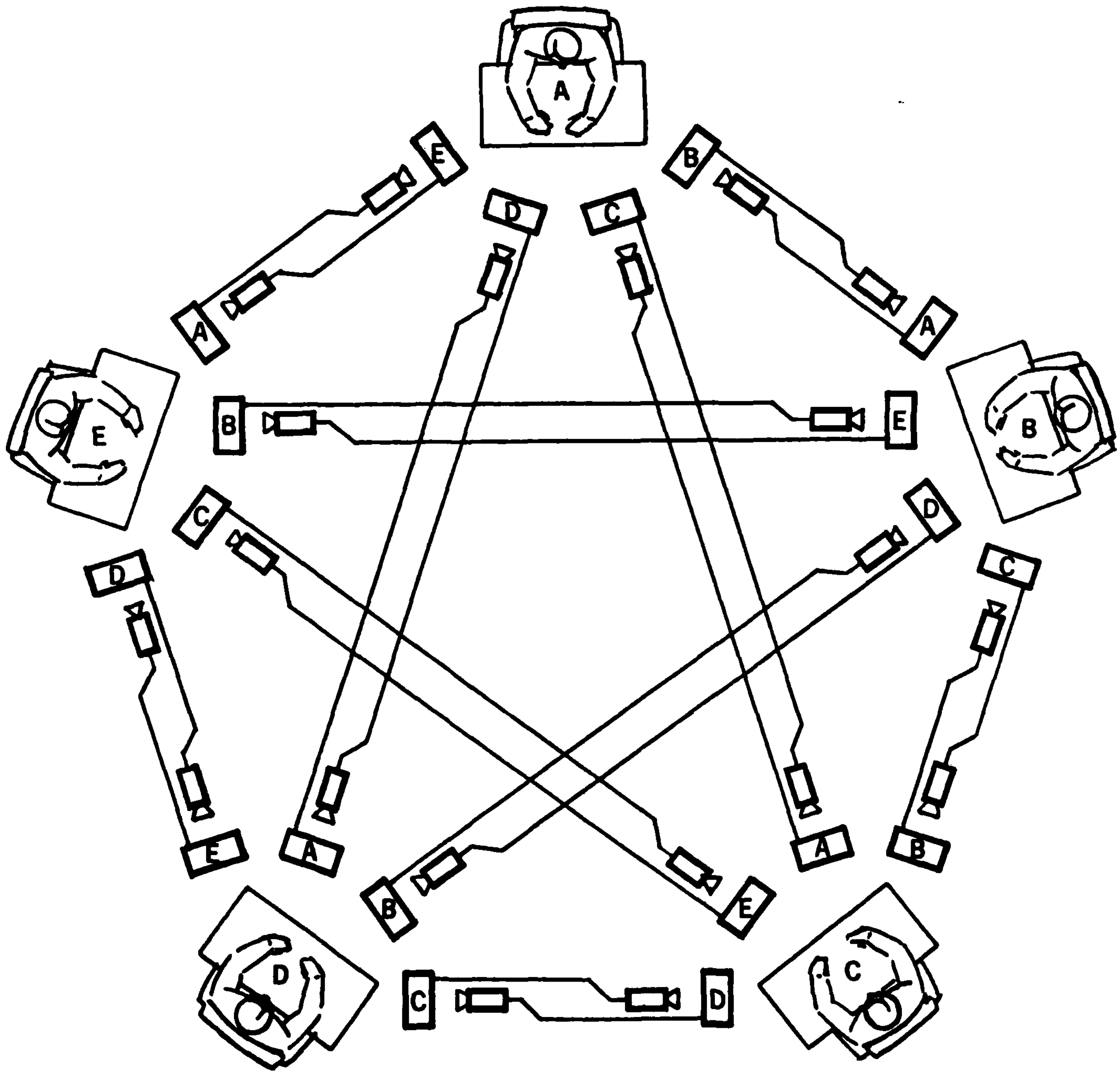

Figure 1

Note that the elements of nonverbal commmunication mentioned earlier are addressed by this configuration. The configuration has the capability of providing the missing elements of the video conferencing system service currently being provided. The most serious problem with such an arrangement has been the costs associated with the large number of audio-video lines. For a three-node system, 6 lines are necessary. For a five-node system, 20 lines are required for a fully distributed network.

The cost of providing such a large number of full video lines is obviously prohibitive. One solution is further compression of the video image.

The video teleconferencing system currently under study at CSM is one which incorporates several key assumptions about the nature of nonverbal communications.

Research has shown that the majority of nonverbal information is communicated by the face. Of this information, the majority of nonverbal information that is communicated is done via the eyes and the mouth. The codecs used in the system currently under study (Compression Labs, Inc. San Jose, California) is optimized using cosine transform technology to perform scene adaptive coding.

The result of this technique is to reduce the content of an image to retain the integrity of motion. This technique results in the human eye serving to incorporate sufficient information through motion to provide adequate nonverbal communication.

The current system under investigation operates at 19.2 Kbaud and provides a image that corresponds to a pencil "sketch" of the face of an individual. For this reason, it is called a "sketch coder".

While the relative transmission rate of frames is approximately 7-10 frames per second, the display quality is high since the image is stored digitally and refreshed at a rate of about 60 frames per second.

Use of the sketch coders for the last year has resulted in a positive evaluation of their use if one considers them a more sophisticated telephone rather than a degraded black and white television picture.

Under the current configuration being developed at CSM, the sketch encoder has been combined with two modes of audio communication. Each station node of the network has the capability of communicating to each of the other nodes as a group or privately.

The "global" communication consists of a shotgun mike placed in an unobtrusive location and transmitted over standard leased lines. The "local" communication consists of an ordinary telephone and autodialer wired with a cutoff switch to the shotgun microphone so that any local conversation is private. In this manner, a user is normally connected with the audio network of the multi-node teleconferencing system. However, if he wishes to have a local (private) conversation with any one of the other conferees, he merely picks-up his private phone and his microphone (and voice) is taken "off-the-air". This arrangement is convenient for those conversations which would normally consist of whispers, aside from the larger meeting.

Each teleconferencing station thus has the capability of face-to-face video, and group or individual communication.

1.5 Shared Data

The second key element of the teleconferencing system under consideration, Shared Data, is an outgrowth of previous work performed on a remote telegraphics system.

The original telegraphics system, called Telepad, (CSM, April, 1981) consisted of a network of five Apple computers in a ring network. The system provides a menu of options, including five "ink" color selection, selection of a common graphics database, and utility functions such as "clear screen".

While of extremely low cost, and of great effectiveness, the original Telepad proved to be adequate only when the subject matter did not require a high degree of information to be passed among the users. The display screen used was 280 x 192 with five colors available. While adequate to display very simple charts, graphs, and simple text, the system was insufficient to display documents and video.

In the current research prototype system, a higher resolution display is used that is capable of displaying 512 x 512 pixels in one of 256 colors using eight bit planes. In the current implementation only eight colors will be used. This will require three of the bit planes and the remaining five bit planes will be used for unique identification codes for the five nodes planned in the system. The unique codes identify each of the individual users. A touch sensitive screen will be used for the shared data space. The monitor is installed in a pedestal surface with the monitor screen forming a writing surface. The touch screen mounted on the face of the monitor will be adjusted so that accidental pressure will not activate the surface.

A stylus will be used to "write" on the monitor in a natural fashion. The color selected by the user will "flow" out onto the screen as it would if the user was writing using a colored pen. A mercury switch is installed in the pen so that when the pen is upended, the opposite end of the pen activates an option so that the stylus becomes an "eraser". The stylus thus serves as an effective model for an environment (pencil) that the user will find conventional and familiar.

In the Telepad project, the menu used by the user was displayed on the video monitor. While this was convenient, it also required using a portion of the already limited display area of the screen for information. In the shared data system, a separate menu box has been installed which permits positive feed back through lighted switches and, by being separate, does not clutter the display.

In addition to these features, a video overlay capability will be provided. When the same videodisk is used by all the conferees the individual users will be able to annotate information accessed from the videodisk, such as maps, and thus share a common set of information.

The net result of the current design should provide an environment which the users will find nearly as familiar to them as a conventional conference.

1.6 Five-node Teleconferencing

The current system under development at Computer Systems Management, links three sites separated by about one mile with a total of five teleconferencing stations. Two stations are at two sites; one station is at the remaining site.

The stations are configured with twenty sketch coders, four per station. Since each sketch coder/ codec is capable of operating at 19.2 Kbps, two codecs may be multiplexed and can share a 56Kb Bell Systems' Digital Data Service channel with a 9.6 line for the telegraphics. The audio communications between is shown in figure 2 below.

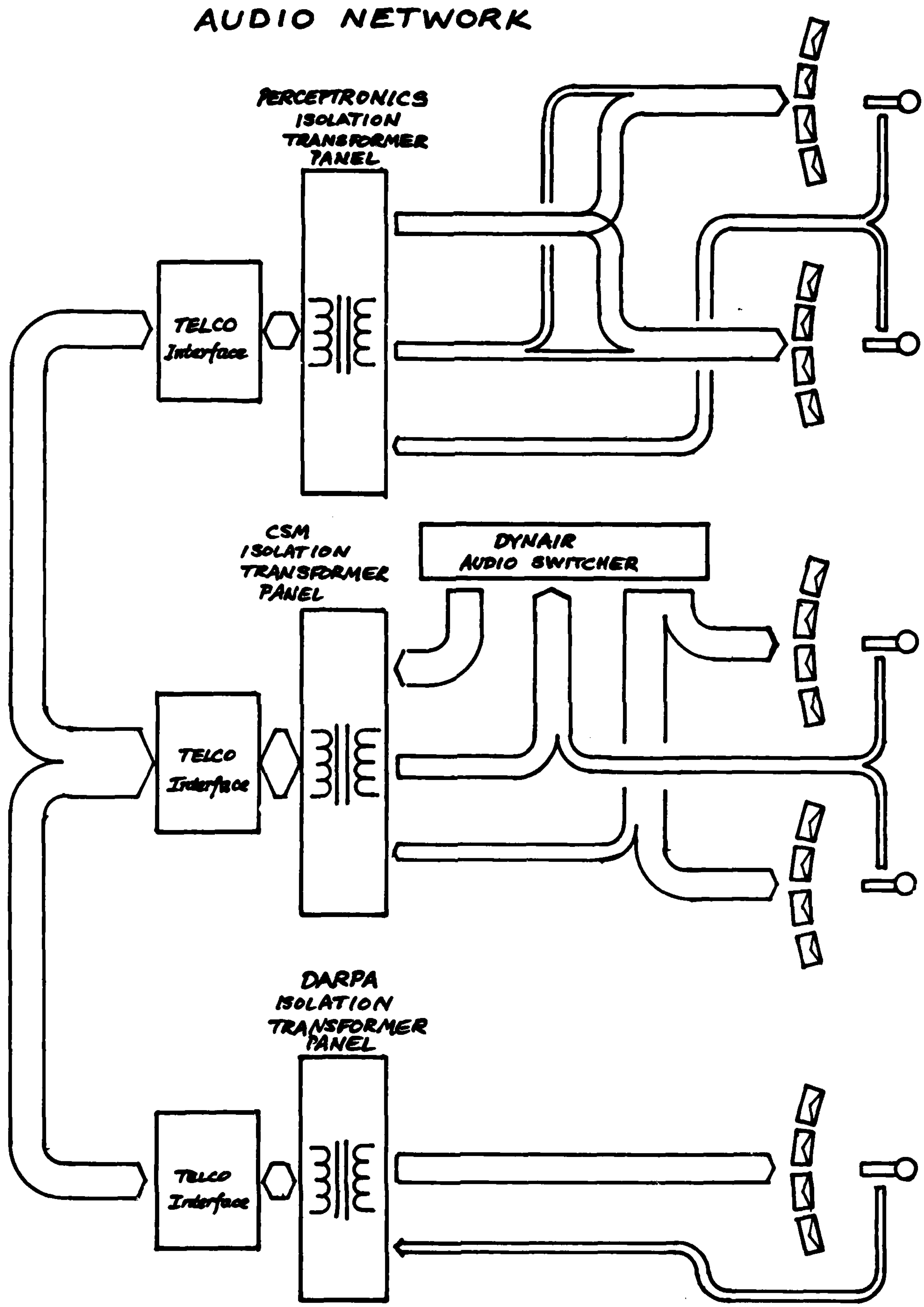
AUDIO NETWORK
PERCEPTRONICS
ISOLATION
TRANSFORMER
PANEL
TELCO
Interface
CSM
ISOLATION
TRANSFORMER
PANEL
DYNAIR
AUDIO SWITCHER
TELCO
Interface
DARPA
ISOLATION
TRANSFORMER
PANEL
TELCO
Interface

Figure 2

1.7 Conclusions

The Teleconferencing system that is currently under-development will be completed by the end of this calendar year. While there has been a great deal of positive comment about the system, one of the negative comments should be addressed.

Many users, especially those who are unaware of the technical considerations, have complained about the low resolution of the sketch encoded images and the low frame rate. When one considers the transmission rate (19.2 Kbps) against that of a full color image (1.5Mbps) and begins to make the trade-offs on a dollar per value basis, the sketch encoded image becomes much more attractive.

If the sketch coder is to be criticized, one might as well criticize the telephone on the same basis. The video content of a telephone is equal to zero. If one considers the teleconferencing station to be an improved telephone rather than a degraded video image, a more positive evaluation may be engendered.

A key advantage not addressed in this article is the issue of cryptography. Full video encryption would be prohibitively expensive if encrypted to the degree necessary to provide approved levels of security. The requirements to create security for the sketch encoded image is well within the means of current technology, such as the Data Encryption Standard.

When the five-node teleconferencing system is completed more extensive evaluations will be performed to analyze the impact of the system on such conferences. The results of the three-node system in use for the last year has been extremely positive.

The key request that has been voiced has been the request for color over black and white. This probably does not add to the content of the information being transmitted using the system, but perhaps the issue of familiarity is of sufficient importance to provide this capability in some form.

More detail concerning the difficulties of system integration and installation will be addressed at the completion of the second phase of the teleconferencing system project. Phase I has been mainly the installation of the CLI sketch coders into a five-node network, complete with audio and video capabilities (virtual space). The second Phase addresses the shared data problem.

2.Ø Micro Spatial Data Management System (MICRO-SDMS)

2.1 Biotechnology

One of the goals of the Systems Sciences Division (SSD) of DARPA/DSO is to develop concepts for biotechnology that reflect ergonomic solutions. In other words, SSD is interested in those aspects of technology that are concerned with the application of biological and engineering data to problems related to man and the machine. Related efforts in the area have caused the development of a research prototype systems called MICRO-SDMS.

The examination of man-machine interfaces reflect the interests of SSD in finding improved solutions to the increasingly complex problems associated with an ever more complex defense environment. These improved solutions involve designing new technology to reflect the way in which human beings deal with the world, rather than trying to force people to adapt themselves to the technology.

As human beings we are primarily a pattern recognizing and pattern using species. Man deals with the world in terms of the internal patterns and symbols he has developed over the course of evolutionary history for that purpose. This ability to recognize and use patterns is a capability which is not possessed by even the fastest of computers.

The computer, on the other hand, is a tool of great speed for repeatedly performing linear tasks. In this capacity, the computer can perform rote tasks at speeds far greater than a human being could attempt, at levels of accuracy that no human is capable of duplicating.

It is no accident that people easily perform those tasks which no computer is capable of emulating, and computers are capable of performing those tasks which no human is capable of duplicating. Both modes of action represent a specialization of function in performing those tasks.

Since both man and machine are capable of performing uniquely useful functions, the question that researchers ask themselves is, "How can these capabilities be combined in the most effective manner?" This question is the basis of cybernetics and biotechnology.

2.2 Representations of Information

Since human beings are most effective at recognizing and using patterns and symbols, the ideal method of presentation of information from machine to man is to present that information in patterns and symbols most easily recognizable by humans.

The presentation of information, represented in its internal form, would be meaningless to all but the most sophisticated of individuals. Most efforts in the computer industry for the last thirty years have been in finding ever more efficient methods to communicate to and from these internal forms.

At the lowest level of external representation, internal computer data is represented in higher numeric bases, a method going back in history to the Babylonians. While this informaton is useful to computer systems developers, the information is still of a low level of appreciation. This representation requires a great deal of training to be comprehensible.

At the next level of representation, computer information is represented in simple mnemonics, again requiring a great deal of training to be comprehensible.

The next level of representation is of very carefully structured languages that require training to interpret, but begins to resemble the modes of representation more common to human beings than to machines. All of the early representational forms are highly structured techniques which allow humans to interact with computers. All have characteristics, that despite appearances, are more machine-like than human-like in nature. As such, these techniques require human beings to adapt themselves to the characteristics of the machine, rather than providing an environment that permits the human being to interact in a easy, natural manner.

2.3 Spatial Representation of Information

People are most comfortable dealing with graphical, symbolical representation of information. Maps are a typical example of this type of information; they represent models of the real world that people may react to as they would react to the actual terrain.

The closer the resemblance of the map to the territory, the more direct the feedback that an individual receives correlating the symbology to the event, the greater the information obtained by the individual.

2.4 Spatial Data Bases

Beginning in 1977, work was begun by Nicholas Negroponte, Richard Bolt and William Donelson at the Architecture Machine Group of the Massachusetts Institute of Technology (MIT) in the development of "spatial constructs of non-spatial data".

Funded in part by the Defense Advanced Research Projects Agency, experiments were conducted in the integration of a wide spectrum of sensory equipment with a multitude of display formats. The goal was to determine which mechanisms provided the most natural means of interaction between man and machine.

It was believed that a natural mode of interaction would have the additional attributes of being the most efficient, the easiest, and quite possible the most economical means of providing information to people.

The outgrowth of this research was the development of the first Spatial Data Management System (SDMS). The first system was incredibly complex, written in machine code, and involved the interafacing of five Interdata computers. Peripheral equipment included videodisk players, graphical tablets, touch sensitive screens, and a projection video system with a variety of display formats.

The impact of the resulting system was phenomenal. Entirely new concepts were developed describing the ways in which individuals could interact with computers to express themselves, to obtain information, and to control processes. While work continued on the SDMS at MIT information about this new breakthrough in the technology spread. DARPA continued to maintain a key role in supporting the continued development of the technology.

In 1979, work began at the Computer Corporation of America to develop a low cost version of the SDMS. The system was to use "off-the-shelf" components and was to be capable of most or all of the functions of the original MIT version. By 1980 a system had been developed which consisted of a DEC PDP 11/70 with three touch-sensitive screens, a data tablet, a joystick and a keyboard. The system was developed in a high level language, "C", and had a specially designed database management system with features appropriate to a graphical environment.

2.5 The MICRO-SDMS

While work was being performed through DARPA funding at MIT, CCA, and other places, industry was continuing the development of new technologies. The microcomputer had continued to drop in price while expanding in capabilities. The videodisk player was developed and was to have an incredible effect on the industry.

Even though the impact of the videodisk as an entertainment medium was grossly overestimated by the industry, it's impact on the educational and scientific communities was vastly underrated. One of the more significant impacts was the development at DARPA and elsewhere of the Micro Spatial Database Management System.

The MICRO-SDMS system was designed with two goals: first, to be constructed from "off-the-shelf" components requiring little or no assembly; second, to be of least possible cost per system. By accomplishing these goals the solution provides maximum distribution to even the smallest of equipment budgets. The configuration can be assembled with merely an equipment list and an instruction sheet describing the component connections.

The system evolved from earlier versions that used a different mix of components. Various peripherals, such as light pens, bit pads, and other forms of input and user control were tested and ultimately discarded. The display format and menu options were changed repeatedly until the most effective were determined. MICRO-SDMS now consists of a micro-computer with disk drive, a monitor with a touch-sensitive screen, and a video disk player. The system is designed so that an untrained user can access information on the videodisk pointing at desired information and by using self-explanatory controls.

At each step consideration was given to providing the most natural human interaction with the system. Dr. Craig Fields of DARPA provided critical direction in the development of the system. His interaction was extremely useful in the evaluation of alternative methods of user interaction. Figure 3 shows the hardware configuration of the final system.

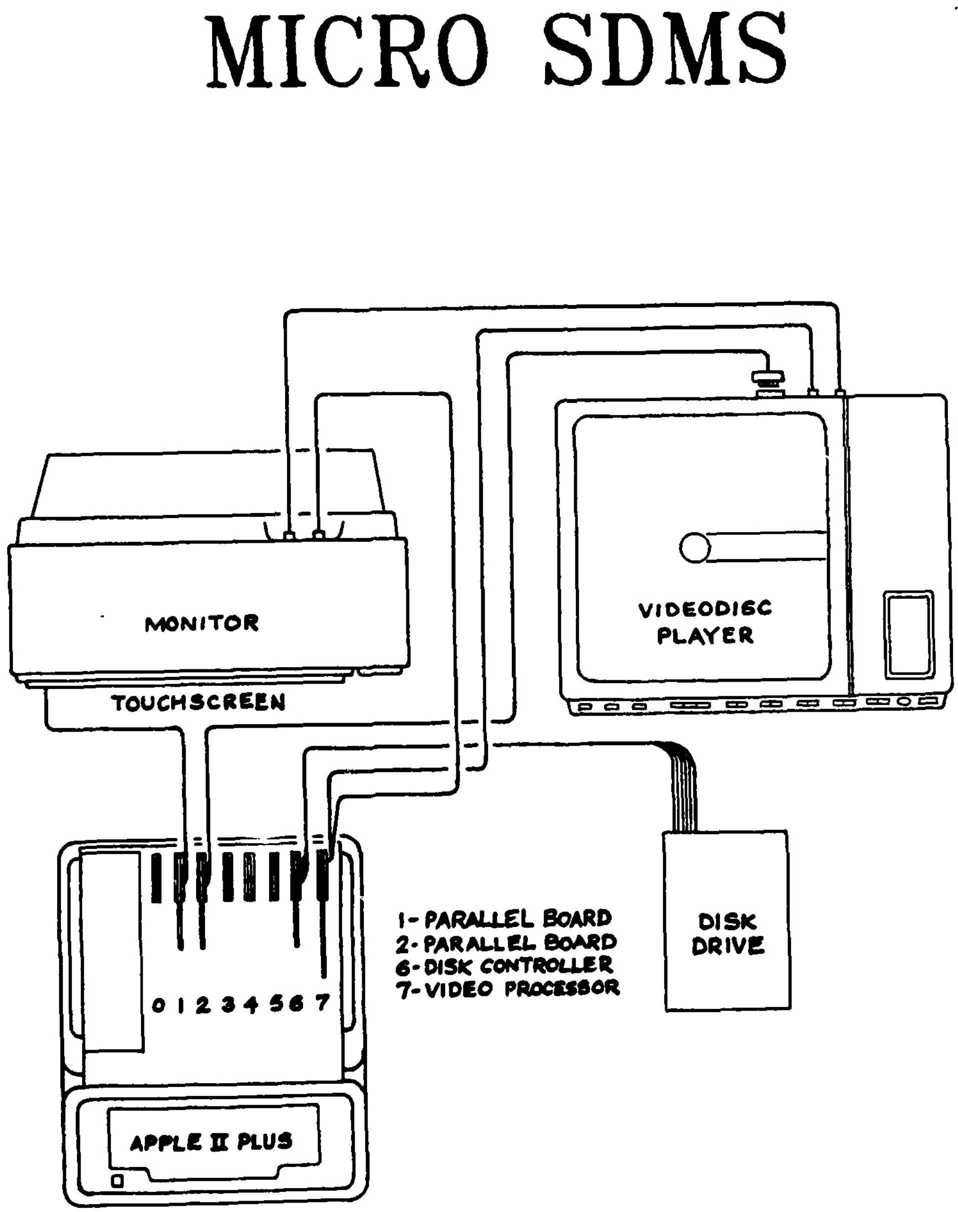

Figure 3

The user of system is presented with a video display overlayed with options for selecting a display or, alternatively, with modification options to the the display currently being reviewed. Great care was taken in selecting the type of overlay characteristics of available commands to be used by the user. Each command is a toggle. Once activated, a command remains in effect until either toggled off; or by progression through the data, the option is no longer germane. For example, the "forward scan" command remains in effect until retouched, whereupon it stops. If the end of data is reached the command disappears from the user's screen and only the "backward scan" command option is presented. This method of display is used to prevent confusing the user. The user is never presented with options which are invalid, thus there is always positive feedback. Every command that is displayed is a command that is capable of having an effect on the display.

The videodisk player used in the MICRO-SDMS system has the capabilty of directly accessing any video frame. Once a frame has been accessed, the videodisk player can function at variable speed or still frame advance. From this set of physical capabilities, a set of options was created to use these capabilities to their best possible advantage. The sofware which operates these commands was written in machine code to provide the greatest response time possible to the user.

The display modification options available on the MICRO-SDMS consist of a selection of any/all of the following list:

MICRO-SDMS COMMANDS

- END PROGRAM - Stops execution of the micro-sdms program.
- ZOOM TOP - Returns to the original menu, the top level menu of the program.
- ZOOM OUT - Returns to the most recently encounterd menu prior to the current menu.
- AUDIO 1 OFF(ON) - Turns the channel 1 audio off(on)
- AUDIO 2 OFF(ON) - Turns the channel 2 audio off(on)
- SLOW FWD - Slow motion forward
- SLOW BACK - Slow motion backwards
- STOP(START) MOVIE - Stops (Starts) movie playing
- FWD 1 SLD - Shows next available slide
- BACK 1 SLD - Shows the previous slide
- SCAN FWD - Shows following slides
- SCAN BACK - Shows previous slides

2.6 Summary

The results of this research task proved that a low-cost, off-the-shelf, list of components could be assembled in such a way as to provide a means of spatial data management to even the most limited of budgets. Further, although unique machine-code software was written to provide user/system interface, it could be easily adapted to data other than what was used as an "example" data base on videodisk. Also new software could be written to permit graphical rather than textially presented icons.

This project used an Apple II plus with a Pioneer laser-disk player model I, which could now be replaced with a model III player. This would delete the need for much of the controlling software. Other advances in the state-of-the-art in microcomputer systems could also provide other acceptable microcomputers rather than relying solely upon the Apple II.

Thus spatial data management can be achieved, with video data, in a low cost environment. Significant programming efforts are unnecessary and a variety of microcomputers can be used.

3.0 Recording Computer Images on Videotape

3.1 Introduction

"C3" is the top objective on the current military list of technological research and development programs. Most of the C3 systems under development rely on a computer to coordinate their functions. Many of these systems use computer-generated graphics to communicate visual information. Given the experimental nature of such graphics systems, they are liable to break down. Yet even in the "proof-of-concept" stage, they are required to perform flawlessly whenever the user, client, or other official wants to see a live demonstration. A conflict arises: Experimental C3 graphics systems are required to perform admirably even in their most elemental phases, yet intermittant breakdown is virtually guaranteed.

Computer Systems Management, Inc. has successfully circumscribed this predicament by substituting videotaped system demonstrations for live demonstrations. In this way, people can see how a prototype system works, without chancing an untimely malfunction.

The most crucial element of such videotaped demonstrations is the close-up of the CRT screen on which the graphics are displayed. This shot shows the viewer exactly what he would see if he were sitting in front of the actual graphics terminal.

This critical shot is difficult to capture on videotape, however. The video production unit of Computer Systems Management, fortunately, has devised a set of alternatives for coping with the technical difficulties of recording computer images onto videotape.

3.2 The Problems and Some Solutions

Because CRT's look like regular TV sets, some naive video producers might think that it is easy to hook them up to a videotape recorder. They might assume that recording graphics terminal images is as easy as taping a late-night movie on a home video recorder. However, this is not the case. For one thing, there is nothing in or on most computer terminals that one can use as an input into a VTR. Unlike a Betamax or VHS machine which connect through the antenna terminals, there are no such connectors or jacks available for hook-up between a CRT and a VTR. So how does one pull the CRT image off the screen and put it on videotape? Computer Systems Management, Inc. has come up with two options. One is rather inexpensive. The other is plain simple.

3.3 Method One

A close-up view of the CRT screen is used most often when the computer graphics system is the star of the show. In fact, these CRT images are the most important aspect of the demonstration since this is where many computer products can show off their "user features". But a close-up of the CRT, wherein the CRT screen fills the entire video screen, is laden with technical difficulties.

The simple method for capturing this image is to merely point the video camera at the CRT screen. This method works equally for all types of displays--raster scan, scan converter, vector graphic, direct-view storage, plasma, laser, holographic, whatever. Unfortunately, the results are equally mediocre.

When pointing a camera at any TV set, you lose resolution and gain moire patterns, wavey scrolling bands, and reflections on the picture tube. These problems are persistent no matter how expensive the camera is. But they can be minimized.

Moire patterns are created when the CRT's scanning lines are at an angle with the camera's scanning. The conflict can be minimized by slightly tilting the camera. The wavey scrolling bands appear when the CRT's display scanning rate is out of sync with the camera's scanning rate. This is most distracting when the CRT screen fills the camera's viewfinder. However when zooming closer or farther away, the problem becomes less noticeable.

Many C3 graphics systems require operator input. Typically, this is done through a keyboard which sits just below the CRT screen. Product demonstrations for this sort of system typically require the camera to "pull back" so that the viewer sees both the CRT screen and the operator's hands working at the keyboard. This situation creates special lighting problems. The hands and the keyboard must be lit, but the CRT screen must not.

Lighting the screen only results in putting bright spots and reflections on the CRT screen. Using no lights results in murky, shadowy, ghostly hands bobbing up and down on an invisible keyboard.

Eliminating the reflections while maintaining adequate light on the hands and keyboard is a matter good of lighting. To minimize the problem, lighting experts suggest lighting the scene as if the CRT was a person (key, back, fill). Unfortunately, this usually floods the CRT screen with light. Not only does that create reflections, but it also dulls the relative brightness of the CRT screen. Careful barn-dooring or flagging can help. Even better, position the lights so that they are all beside or behind the CRT, with light hitting the hands and keyboard but not the screen itself. Thus the operator's hands will never fall into the shadows, nor will there be a bright spot on the screen.

If a bright spot persists on the screen, moving the CRT or the camera just a bit will help. Quite often, spots at the top of the screen can be erased by tilting the CRT forward. If it is a lightweight CRT, simply slip a black videocassette box beneath the back of the unit. Since it is black and in the shadows, the viewer never notices it. Never use dulling spray if the CRT is the star. It acts like putting a veil over the star actress. Her face will not show very well.

Reflections of another sort plague the CRT screen too. Like any shiny object, these reflections eminate from the objects around them. Windows, overhead lights, tripod legs, even brightly colored walls will appear on the CRT screen. A simple and effective way to eliminate these is to cover the troublesome objects with black cloth. A 6'x8' remnant of black felt and two pairs of large alligator clips should do.

The most vexing problem is seeing reflections of the operator himself on the CRT screen. This is particularly noticeable on a close-up of the CRT screen. The best solution is to kill all the lights, zoom in so that the CRT screen fills the shot, and let the screen's own phosphers illuminate the scene. Beyond that, careful camera angling and barndooring will have to do.

3.4 Method Two

For the most part, we have been discussing how to capture close-ups of a CRT screen. Such a close-up view is used often when the computer is the star, since this is where many computer products can show off their "user features". Quality here is critical, and oftentimes pointing the camera at the CRT simply will not do.

A second albeit more expensive alternative requires a piece of electronic gear known as an NTSC encoder. This device transmits the video signal directly from the computer and will send it directly to a videotape recorder. No camera required. The resulting footage can be edited and mixed with other live and recorded sources.

It is not easy to get a computer video signal processed to the point where it is stable enough to be recorded and mixed. This is because few CRT displays use the NTSC video standard to generate their images. Some systems have 1025 scanning lines, compared to NTSC's 525. Some do not even have scanning lines at all. (Vector graphics and plasma use radically different methods for throwing an image on the screen.)

For example: Apple computers show up on regular TV monitors. But their signals can not be recorded on a standard VTR. The reason is, because Apples (and similar personal computers) can be displayed on standard TV sets because today's sets have a high tolerance for signal discrepancies. Thus, they can handle the computer signals even if the signals don't have the requisite front-porches, back-porches, and breezeways that video engineers need for "good video".

Recording and playing back such Apple signals is much more difficult than simply tapping the patch panel on the back of the computer console. The Apple signal is a non-standard NTSC signal; it has 524 lines of resolution instead of the standard 525. Special circuit boards must be plugged into the Apple to add the 525th line. Even then, some of the circuit boards designed for this purpose only enable the signal to be laid down and played back. They don't process the signal to the point where it can be edited with other sources. That requires a more expensive circuit board.

Similar problems apply to all types of sophisticated computer image signals. They all require some sort of processing before they can be recorded and edited. The only equipment which does this sort of processing are the new digital effects systems which may cost hundreds of thousands of dollars. It is sufficient to say that most computer signals need processing to enable them to be recorded and edited.

RGB displays are today's most popular computer imagery systems. They generate a rainbow of colors by first producing the right amount of red, then the right amount of green, then the right amount of blue. This contrasts with the NTSC system which essentially mixes luminance, saturation, and hue simultaneously.

To pull an RGB signal out of the computer, you need two things, an RGB-to-NSTC encoder and an output from the graphics system into which you can plug the encoder. If you are lucky, these things are already available alongside all the rest of the computer gear. However in most computer facilities there is no encoder in sight.

The next trick is finding the place to plug it in. The encoder has three BNC-connector inputs (one each for red,green, and blue). They must be hooked up to the computer's auxillary RGB outputs, which of course are not guaranteed to be nearby the CRT. In fact, the CRT being taped and the place where it can be tied into the encoder may be in completely different rooms. Depending on the nature of the video production, this may require several extra long BNC cables.

Always ensure that the encoder is compatible with the particular computer system. Some producers who use such encoders find their material is consistently under-saturated. Others have no such problems. Encoders are rack-mountable. In order to record images from the same computer over and over, it can be left in the computer room. If it is needed for "remotes" in several facilities, the encoder is small enough (18"x8"x1") and lightweight enough (2 lbs.) to fit in an accessory case . The encoder has a few simple knobs that need adjusting so it helps to have a waveform monitor available.

The output of the encoder is usually clean and attractive. But it is not always up to the client's expectations. For one thing, even if the computer image has the same aspect ratio as video, the encoder underscans the image. As much as 15% of the top, bottom, and sides may be lost. Since computer programmers know nothing about "safe areas" when making their images, they may put key information along the screen border. This may be lost.

Another problem with the encoders is the perception that they degrade the image quality. Though this may be true to a slight degree, the problem is typically something else. Many of today's computer imaging systems have more than 525 lines of resolution. Thus the resolution must be reduced to comply to NTSC standards. Yes, the signal is degraded, but only because that is the limitation of American television (NTSC).

The final problem with the encoder is that it is not flexible. It always shows the whole screen; it is difficult to zoom to get an extreme close-up of a special segment of the screen. This is particularly frustrating when trying to read text. Television graphics standards recommend no more than eight lines of copy; after that, it is too small to read. CRT's however have higher resolution and are viewed only inches away from the eyes. Thus, the CRT legibility standard is 20 or even 40 lines of copy. When displayed on video, it is difficult to read. The only solution beyond re-programming the software is to go back to pointing the camera at the CRT screen (and incurring all the above mentioned ailments).

3.5 Conclusion

So there it is. The plain simple way of capturing CRT images on videotape is to aim the camera at the screen. Although it permits infinite zooming and it permits including a person interacting with the equipment, it requires time-consuming lighting and careful camera angling trying to negate fuzzy, wavey-lined, washed-out images.

The more expensive way is to utilize an encoder. It produces cleaner, brighter, more colorful images, but with less resolution, no border images, and less flexibility of zooming in. The best solution is to plan the shots well in advance, decide which can be done best with a camera and which with an encoder, and use BOTH methods to produce the most legible production given the limited status of today's computer/video interface technology.

3.6 SUMMARY

Prototype C3 systems currently under development tend to break down during live demonstrations. One way to avoid this untimely malfunction is to use videotaped system demonstrations instead. A problem arises however, because capturing computer images on videotape is technically difficult. One method entails pointing the video camera directly into the CRT screen. A more satisfactory method requires the use of an encoding device. Neither method produces a high-quality image. But, both methods generate images that are acceptable for video demonstration purposes, and they avoid the mishaps that can occur during live demonstrations.

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